10/068,935

TITLE OF THE INVENTION

A ROOF VENT SYSTEM WHICH PREVENTS ROOF LOSS / LIFT OFF IN HIGH WINDS

Do Not Enter SubSpec

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CROSS-REFERENCE TO RELATED APPLICATIONS

6,484,459 B1	11/2002	Platts
4,144,802	03/1979	Babin

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not Applicable

BACKGROUND OF THE INVENTION

1) Field of the invention:

This invention relates to the effects of high winds (hurricanes and tornadoes) on the roof structures of buildings. It is an invention for a roof vent system, which prevents roof loss due to high wind events. It does this by limiting the pressure difference that can occur across the roof of the structure to a set value. The system is made of simple components, which are inexpensive and do not compromise the system's effectiveness as they age. As such it addresses in a cost effective and quantitative manner, the problem of roof loss that is associated with high-speed winds.

2) Related art:

The related art (Babin, 4,144,802…03/1979 and Platts 6,484,459…11/2002 also deals with roof vent systems. One facet of Babin's system is that it uses vents to release, relieve or equalize the pressure differentials that can develop across a roof during high wind events. The downfall of this system as I see it is that whilst equalization, relief or pressure release occur the system does not prevent pressure differentials from developing which might be sufficient to lift off the roof.

The Platts, system is designed to drop the pressure inside the building to help protect the roof, but it does not ensure that the interior pressure drops at a sufficient rate to prevent a pressure differential developing that is sufficient to lift off the roof. Again, it is not designed to absolutely limit the pressure difference that can occur.

Summary

This is a system of roof vents, which prevents a pressure difference across a roof (i.e. between the interior and exterior of the building) sufficient to lift the roof off. (This system limits the pressure difference that can occur across a roof). It involves a calculation, which quantifies the surface area of open venting that is required to prevent roof loss for each given building. It also specifies where that venting must be placed on the roof of the building. I have described three different vents, which represent the preferred venting design options to be used in this system. All three designs are aerodynamic, such that any high-speed winds blowing over the roof blow through the vent with minimal reduction in speed. The vents are open, allowing bi-directional flow of air. There is a central plug, which closes them and they may remain closed at all times except when there is high wind risk. The central plug in two of the designs is mechanically opened by direct exposure to a sufficient pressure difference. The central plug in the other design is opened by a spring mechanism, which is triggered by a pressure difference-sensing device.

In the prior related art, there have been vent systems, which release, relieve, or equalize pressure across a roof. There have also been systems that intend to create a negative interior pressure in buildings subjected to high winds. None of these systems ensure that (on the way to equalization, or to the creation of a negative pressure inside the building) a pressure difference does not develop which will be sufficient to lift off the roof. These systems are not designed to limit the pressure difference that can occur across a roof.

DESCRIPTION OF DRAWINGS

Fig 1a and Fig 1b: These are graphical representations highlighting the difference between a roof vent systems that release/relieve or equalize a pressure differential and my system, which places a limit on the magnitude of a pressure differential.

Fig 2: Illustrates air movement above and below a roof.

Fig 3: Illustrates the forces acting on a roof.

Fig 4a through 4f: These figures outline the design of vent type A.

Fig 5a through 5e: These figures outline the design of vent type B.

Fig 6a through 6c: These figures depict vent type C.

Fig 7: Illustrates a step down profile roof.

Fig 8: This is a maximum measured wind acceleration graph.

Fig 9: These are potential graphs of pressure as relates to wind velocity.

Fig 10: Graph of potential pressure changes with respect to time.

Fig 11a: Illustration of the angle at which pressure acts against the interior of a roof.

Fig 11b: Illustration of the weight versus pressure angle of action on a roof.

Fig 12: Graphical representation of a useful interior/exterior pressure change relationship.

Fig 13: Graphical representation of straight line pressure change.

Fig 14: Graphical demonstration of how this applies to non-linear pressure change.

Fig 15a through 15d: Illustrations highlighting how the venting area must be just sufficient to evacuate air from each room of a building.

Fig 16a and 16b: These pictures illustrate air flow over porches and eves.

Fig 17: Illustration of how wind shear will affect the venting density.

Fig 18: Picture of vents spread evenly across the roof area.

Fig 19: Diagram illustrating the fact that when the wind blows from certain directions only a portion of the roof may be exposed to high wind exerting a venturi effect.

DETAILED DESCRIPTION OF INVENTION

FORCES ACTING ON A ROOF

As fast flowing air passes over a roof, there is a resulting lowering of pressure. (Venturi effect and turbulence) See Fig 2

Thus the pressure outside the roof is lower than the pressure inside the roof. Pressure is a force/unit area. In order for the roof to lift off of a house, the forces acting upwards must be greater than the forces acting downwards. See Fig 3

In the simplest equation format, if

$$\left[\frac{\text{Weight of Roof}}{\text{Unit Area}} + \text{External Pressure} \geq \text{Internal Pressure}\right]$$

then a roof will always stay on. There is no net force upwards.

It should be possible to quantify with a degree of accuracy the minimum tensile strength of the connections linking the roof to the walls as well as the minimum tensile strength of the roof material itself. These factors can then be incorporated into the above equation to give a more accurate value for the maximum allowable pressure difference.

$$\frac{\text{Weight of Roof}}{\text{Unit Area}} + \text{Tensile strength of connections} + \frac{\text{External Pressure}}{\text{Unit Area}} \geq \frac{\text{Internal Pressure}}{\text{Unit Area}}$$

$$\frac{\text{Weight of Roof}}{\text{Unit Area}} + \text{Tensile strength of connections} \geq \frac{\text{Internal Pressure - External Pressure}}{\text{Unit Area}}$$

These equations illustrate that the air pressure difference between the interior and exterior of the building acting upwards must at all times be less than the weight/area of roof plus the factored effect of the tensile strength of connections and roofing material acting downwards.

In order to allow air to flow across the roof and thus control this pressure difference vents are used.

PREFERRED VENT DESIGNS

Ideally one wants the vent design to be as streamlined as possible so that the air passing through the vent is travelling at the same speed and creating the same lift effect as the air flowing over the adjacent roof. Wind tunnel tests that quantify the friction of air flowing through the vents will allow a compensating adjustment of the calculated minimum venting area required. (This friction is that experienced by the air passing in under the vent cap and out the other side, not the air moving from the interior of the building through the vent to the exterior.)

1) Vent design (A)   See figs 4a through 4f.

Vent (A) Performance Points

1) Cap prevents rain from entering, (even most horizontally blown rain).
2) Cap is smaller than base plate so that bars slope in. This makes it more difficult for blown debris to catch on the vent.
3) Vertical bars are spaced such that the gap size doesn't allow bees access. (vents cannot become hive sites)
4) Any water that does enter the vent shaft is collected and channeled through a tube into the drains. The tube might alternatively direct the water outside the building, if this proves easier.
5) The central plug is 'free floating' on a central shaft. Its weight / area is, let us say 60% of the maximum allowable pressure difference. This means that at a pressure difference greater than 60% of the maximum allowable the plug will be pushed up, thus opening the vent. (The 60% figure is set so that the vent will be open by the time the maximum allowable pressure difference is reached. I.e. wind acceleration from 60% to 100% does not outpace the speed at which the vent opens. This 60% value might need to be 50% or 90%, whichever is calculated as appropriate.)
6) Once the central plug is pushed up it acts like an airplane wing. Air rushing through the vent 'flies' the central plug up on its shaft. The vent stays open as long as high-speed winds are blowing through it. When the wind speed drops the plug sinks down to close the vent.

2) Vent Design (B)   See figs 5a through 5e

Vent (B) Performance Points

1) Cap prevents rain from entering, (even most horizontally blown rain).
2) Cap is smaller than base plate so that bars slope in. This makes it more difficult for blown debris to catch on the vent.
3) Vertical bars are spaced such that the gap size doesn't allow bees access. (vents cannot become hive sites)
4) Any water that does enter the vent shaft is collected and channeled through a tube into the drains. The tube might also direct the water outside the building, if this proves easier.
5) The central plug is pushed open by a spring. A pressure difference-sensing device triggers the spring. The pressure-sensing device is set to trigger at a fraction of P^* (say 60%) such that the vent is opened before P^*, the maximum allowable pressure, is reached.

Both of the preferred vent designs need only be opened in hurricane/tornado conditions. The rest of the time they can remain shut to prevent heat loss from the house. (If so desired)

CONSIDERATIONS OTHER THAN VENTS

1) Increasing the weight of the roof will make it more difficult to lift off (e.g. attach weights to rafters, or the plywood roof sheeting). The disadvantage to this however, is that in the event of a building collapsing or being blown down there is the potential for a lot of heavy weight landing on someone.
2) Decreasing wind speed over the roof. (I am not convinced that it would be possible to effectively limit wind speed by creating a certain roof profile)
See Fig 7

3) Increasing the tensile strength of roof connections and roofing materials. This should be effective, however it means replacing existing roofs with higher quality materials, which is expensive (both the materials and the cost for replacement)

Each methodology has its distinct advantages and drawbacks. I suspect though, that the cheapest and most effective way to prevent a building from loosing its roof will prove to be the vent system approach.

THE USE OF VENTS, A CALCULATED NUMBER (SURFACE AREA OF OPEN VENTING) WITH RESPECT TO VOLUME OF BUILDING.

1) Data of wind accelerations must be taken. (Can be found or measured at a meteorological station, military records, or from storm chasers recordings) What is needed is the maximum wind acceleration ever recorded, i.e., the fastest change of wind speed observed for the event that you wish to rate the building for.

2) Then take the fastest wind velocity recorded e.g., might be 180 mph in hurricane situations or up to 300 mph in a tornado. The data you choose to input is aimed at quantifying a worst case scenario for pressure change above a roof.
Take the value of the maximum recorded acceleration of wind and apply it from velocity = 0 up to a maximum wind speed expectation. This will give the greatest pressure change over the smallest time period that can possibly occur above a roof based on historical precedent. (One might even choose as an insurance to put in values slightly larger than have been measured.) <u>See Fig 8</u>

The next step is to link a given wind speed to a specific pressure value. This data can be generated using a wind tunnel and any suitable pressure-measuring device.

Using the wind tunnel blow wind speeds from 0 mph up to your maximum expected velocity. Take the pressure-measuring device and measure the greatest pressure drop that corresponds to each wind speed. From this a graph of pressure versus wind velocity can be plotted. Obviously initial atmospheric pressure may vary, however it is the pressure change between velocity 0 and the maximum expected velocity that is important. <u>See Fig 9</u>

Using the pressure relative to velocity results plot pressure versus time based on the maximum measured wind acceleration to reach the maximum expected wind speed. This produces a graph, which describes the greatest pressure change that can occur in the shortest possible time above a roof: In other words, the worst-case scenario that would need to be dealt with.

<u>See Fig 10</u>
Incorporated with this must be a consideration of the atmospheric pressure shift that is associated with a change in temperature (recorded as barometric pressure). The rapidity with which this may cause a pressure change above a given location should be factored in with the maximum pressure change value associated with high-speed winds.

An alternative quantification method would be to set a continuously recording pressure-sensing device out in various high wind events (hurricane, tornado). This would provide data for comparison with wind tunnel tests.

At this point the maximum pressure change that can occur in the shortest period of time above a roof is known. Therefore one knows what pressure change must occur inside the

building to prevent a pressure difference (P^*) between the inside and outside of the roof sufficient to lift the roof off.

The pressure difference between the inside and outside of the building must at all times be below a certain value. That value is the one at which point the roof will lift off. As explained earlier this value can be calculated very exactly using the weight of the roof/unit area, the tensile strength of attachments to walls, wall weight etc. However, one could also just build in a safety margin and make the maximum allowable pressure difference the weight/area of the roof ($^4/_5$ weight/area or $^3/_4$ i.e., whatever safety margin one chooses to create).

I will show scenarios using the weight/area of the roof as the allowable pressure difference.

It should be noted that pressure acts perpendicularly to a given surface. See fig 11a

So in the case of a roof the pressure acts perpendicularly to the roof surface whereas weight acts directly downwards. See fig 11b

Thus more accurately the pressure difference must be less than the weight/area (cosϑ) to prevent roof loss.

Pressure inside - Pressure outside = P^*

P^* must be less than roof weight/area (cosϑ).

$P^* <$ weight/area (cosϑ).

Knowing the exterior pressure change (worst-case scenario data) one knows what the interior pressure must match to be within the allowable P^*.

See Fig 12

So we have defined what the interior pressure curve must be to be useful (i.e., prevent roof loss). Now it is necessary to calculate the area of roof venting (number of vents) necessary to achieve this.

1) Calculate the number of moles of gas (air) which must be removed from the interior of the building to bring the pressure difference within the allowable P^* at the point of lowest external pressure (max wind velocity).

Using the gas equation $PV = nRT$

P = pressure	n = number of moles	
V = volume	R = gas constant	T = temperature

I will be using the sign ↓ to indicate a known value

The initial interior pressure = initial exterior pressure.

Thus the number of moles of gas initially inside the building can be calculated:

$$\overset{\downarrow}{P}\overset{\downarrow}{V} = n\overset{\downarrow}{R}\overset{\downarrow}{T}$$

$$\left[n = \frac{PV}{RT}\right]$$ * call this n_i (n initial)

Pressure is known
Volume of building is known
R is the gas constant

Temperature can be set at a typical value for a high wind event in that region. (To be on the safe side, set the temperature at a lower value than it is ever likely to be. This will make the n (number of moles) to be evacuated larger than it will ever have to be. I.e., a built-in safety margin).

For the final interior pressure, take the value of final exterior pressure + P^*, since it must remain within the allowable P^* constraint.

Again using

$$\overset{\downarrow}{P}\overset{\downarrow}{V} = n\overset{\downarrow}{R}\overset{\downarrow}{T}$$

$$\left[n = \frac{PV}{RT}\right]$$ * call this n_f (n final)

Again, n (number of moles) is calculated and this n_f represents the maximum number of moles that may remain in the building to meet the P^* constraints which have been set.

Thus $n_i - n_f$ = n moles of gas which must be evacuated from the building to keep P^* within its set constraints.

This n moles of gas will have a certain mass (i.e., composition of air %N, 0_2, $C0_2$, etc.) which can be calculated.

The volume of gas which must leave the building can also be calculated if the number of moles which must be evacuated is known.

Using $\overset{\downarrow}{P}V = \overset{\downarrow}{n}\overset{\downarrow}{R}\overset{\downarrow}{T}$ $$\left[V = \frac{\overset{\downarrow}{n}\overset{\downarrow}{R}\overset{\downarrow}{T}}{\underset{\uparrow}{P}}\right]$$

n is known
R is constant
T has been measured/set

P average pressure can be calculated

Pressure is changing over the time period. A fixed number of moles of gas will occupy more volume at low pressure and less at high pressure. By using the value of the average pressure over the time period, the volume of air that must exit can be calculated.

<u>Summary of what is known for any given building</u>
(I.e. what can be calculated)

1) The time over which the pressure change occurs (worst-case scenario data).
2) The number of moles which must be evacuated from the building.
3) The mass of gas which must be evacuated.
4) The volume of gas which must be evacuated.
5) The $P*$ (this is chosen).

Now it is possible to write some equations.

(1) The equation for the volume of air exiting the building

volume *(vol)* = vent area *(area)* × *(v)* average air velocity through vents × *(t)* time air is flowing through vents

(2) Pressure = $\frac{\text{Force}}{\text{area}}$

This is the driving force of the air leaving the vents ($P*$).

$$P* = \frac{Mass\ of\ air\ (m) \times acceleration\ (a)}{area}$$

(3) We have set a maximum allowable $P*$. This means that acceleration is constant once $P*$ is reached. ($P*$ is constant and thus acceleration is constant over the critical time period.) The following equation can be written when acceleration is constant and it acts to link the first and second equations.

$$(v)\ velocity\ (average) = \frac{a\ (acceleration)\ t\ (time)}{2}$$

This equation is only true if the initial velocity is zero. That is not the case here. When $P*$ is reached the initial air velocity through the vents is definitely not zero. This means that the actual average velocity generated by this $P*$ will be higher than the value given by this equation. It therefore follows that the minimum vent area given by this equation will be slightly larger than the actual minimum vent area required. This can be looked at as a cushion, or safety measure. A more complex and accurate equation can I am sure be generated later if necessary. I will use this simple equation to illustrate that it is possible to quantify a minimum vent area required to keep a $P*$ value within its set constraint.

So taking these three equations with the three unknowns, it is possible to substitute and solve for a minimum vent area required to ensure that $P*$ stays within its limit.

(1) $vol = area \times v \times t$

(2) $P* = \dfrac{force}{area} = \dfrac{ma}{area}$

(3) $v = \dfrac{at}{2}$

Substituting (3) into (1) gives (4)

(4) $\overset{\downarrow}{vol} = area \times \dfrac{\overset{\downarrow}{at}}{2} \times \overset{\downarrow}{t}$

from (2) $a = \dfrac{area\,\overset{\downarrow}{P*}}{\underset{\uparrow}{m}}$ substitute this into (4) to give (5)

(5) $\overset{\downarrow}{vol} = area \times \dfrac{area\,\overset{\downarrow}{P*}}{2\underset{\uparrow}{m}} \overset{\downarrow}{t}{}^{2}$

(5) $\overset{\downarrow}{vol} = area^{2}\, \dfrac{\overset{\downarrow}{P*}\,\overset{\downarrow}{t}{}^{2}}{2\underset{\uparrow}{m}}$

As previously stated ↓ indicates known values so the area can be solved for:

(6) $area = \sqrt{\dfrac{\overset{\downarrow}{vol} \times 2\overset{\downarrow}{m}}{\underset{\uparrow}{P*}\,\underset{\uparrow}{t}{}^{2}}}$

<u>Terminal Velocity</u>

When the $P*$ for equation (6) is set and the area of open venting required is calculated, no account of the resistance of friction was taken. The next step is therefore to include this to give a more accurate equation.

The friction force will oppose the drive of the $P*$ force, meaning that a given $P*$ will result in a smaller acceleration and therefore velocity than projected, with a consequent decrease in interior pressure change/time.

The friction (f) offered by a given area of venting is related to the vent design, and the velocity of airflow.

$f = kv$ for low wind speeds
$f = kv^2$ for higher wind speeds

In order to quantify the friction, tests must be run on the vent type chosen

(1) Maintain a known constant pressure difference.
(2) Measure the terminal wind speed through the vent, i.e., the maximum wind speed which results from that set pressure difference.

At terminal velocity (v_t)

for low speed wind $P^* - kv_t = 0 \rightarrow v_t = \frac{P^*}{k}$

for high speed wind $P^* - kv_t^2 = 0 \rightarrow v_t = \sqrt{\frac{P^*}{k}}$

Note that P^* represents a $\frac{force\,(ma)}{area}$

The total force will therefore be $\frac{ma}{area} \times vent\ cross\ sectional\ area$

Thus with a known set P^* and a recorded *vt* it is possible to calculate a value for k for that specific vent type. This value corresponds to a certain area of vent (i.e., vent surface area dictates total force (ma) exerted since driving force P^* is $\frac{ma}{area}$)

The equation:

$$\text{(A)} \quad \frac{m\left(\frac{dv}{dt}\right)}{area} = P^* - \frac{kv}{area}$$

can be written from Newton's second law (low speed)

$$v_t = \frac{P^*}{k} \qquad\qquad P^* = \frac{ma}{area}$$

Using an area corresponding to the cross-sectional area of one vent is convenient since that is what k and *vt* values are based on.

Now (A) can be written

$$\text{(A)} \quad m\frac{dv}{dt} = ma - kv \qquad \text{and} \qquad v_t = \frac{ma}{k}$$

divide (A) by -k

$$\frac{-m}{k}\frac{dv}{dt} = \frac{-ma}{k} + v \qquad\qquad \text{substitute } -v_t \text{ for } \frac{-ma}{k}$$

$$\frac{-m}{k}\frac{dv}{dt} = -v_t + v$$

$$\int_0^t \frac{-k}{m} dt = \int_0^v \frac{1}{v - v_t} dv$$

$$\frac{-k}{m} t = \ell n \frac{v_t - v}{v_t}$$

$$e^{\left(\frac{-k}{m}\right)t} = 1 - \frac{v}{v_t}$$

(B) $$v = v^t \left(1 - e^{-\frac{k}{m}t}\right)$$

Equation (B) can be substituted into equation (1). The definite integral of equation (B) between any two time limits will be a more accurate replacement for the v (average velocity) x t (time air is flowing) portion of equation (1).

$$volume = total\ vent\ area \times \int_0^t v_t \left(1 - e^{-\frac{k}{m}t}\right)$$

$$\int_0^t v_t - v_t e^{-\frac{k}{m}t} = \left[v_t t + v_t \frac{m}{k} e^{-\frac{k}{m}t} \right]_0^t$$

(D) $$\text{Total Vent Area} = \frac{vol}{\left[v v_t + v_t \frac{m}{k} e^{\frac{-k}{m}t} \right]_0^t}$$

Equation (D) would be correct for low velocities of air flow where $f = kv$.
For high velocity where $f = kv^2$

$$P* - kv^2 = 0 \ at \ v_t$$

$$v_t = \sqrt{\frac{P*}{k}} = \sqrt{\frac{ma}{k(area)}}$$

Again, make the area the area of the roof vent since *k & vt* are calculated from that.

$$m\frac{dv}{dt} = ma - kv^2 \qquad \text{divide both sides by } k$$

$$\frac{m}{k}\frac{dv}{dt} = \frac{ma}{k} - v^2 \qquad \text{substitute } v_t^{\,2} = \frac{ma}{k}$$

$$\frac{m}{k}\frac{dv}{dt} = v_t^2 - v^2$$

$$\frac{m}{k}\left(\frac{1}{dt}\right) = \frac{v_t^2 - v^2}{dv}$$

$$\frac{k}{m}dt = \frac{1}{v_t^2 - v^2}dv$$

$$\int_0^t \frac{k}{m}dt = \int_0^v \frac{1}{v_t^2 - v^2}dv$$

$$\frac{k}{m}t = \frac{1}{2v_t}\ell n\left|\frac{v_t + v}{v_t - v}\right|$$

$$2v_t\frac{k}{m}t = \ell n\left|\frac{v_t + v}{v_t - v}\right|$$

$$e^{\left(\frac{2v_t k}{m}\right)t} = \frac{v_t + v}{v_t - v}$$

$$\text{(E)} \qquad \left[\, v = \frac{v_t e^{\left(\frac{2v_t k}{m}\right)t} - v_t}{1 + e^{\left(\frac{2v_t k}{m}\right)t}} \,\right]$$

As before the definite integral of equation (E) will be a more accurate replacement for the *v* (average velocity) x *t* (time air is flowing) portion of equation (1).

$$\text{(1)} \qquad \text{vol} = \text{total vent area} \times \int_0^t \frac{v_t e^{\left(\frac{2v_t k}{m}\right)t} - v_t}{1 + e^{\left(\frac{2v_t k}{m}\right)t}}$$

let $c = \dfrac{2v_t k}{m}$ to make the notation easier

$$\int \frac{v_t e^{ct} - v_t}{1 + e^{ct}} dt = -v_t \int \frac{1 - e^{ct}}{1 + e^{ct}} dt = -v_t \int \left(1 - \frac{2e^{ct}}{1 + e^{ct}}\right) dt$$

$$= -v_t \int 1 dt + \frac{2v_t}{c} \int \frac{e^{ct} c}{1 + e^{ct}} dt$$

$$\begin{bmatrix} \textit{let } u = 1 + e^{ct} \\ \therefore \dfrac{du}{dt} = e^{ct} c \\ \Downarrow \textit{ substituting } u \textit{ and } \dfrac{du}{dt} \\ \displaystyle\int \frac{\frac{du}{dt} dt}{u} \end{bmatrix}$$

$$= \left[-v_t t + \frac{2v_t}{c} \ell n\left(1 + e^{ct}\right) \right]_0^t$$

Equation F

$$\text{Total Vent Area} = \frac{Vol}{\left[-v_t t + \dfrac{m}{k} \ell n \left(1 + e^{\frac{2v_t k}{m} t} \right) \right]_0^t}$$

These equations are true for the straight-line scenario of external pressure change.

<u>See fig 13</u>
They hold true for any pressure drop, which is a straight-line graph between two time points. They are therefore also true for a curved graph pressure drop as long as the increment t taken is tended to 0 (i.e., very small so appears like a straight line).

See Fig 14

Looking at the previous example graph, if equations (6), (D) or (F) are used with the end points $t = 0$, $t = 3$, the predicted vent surface area required will correspond to the straight-line pressure change. P^* will go above and below the preset constraint and so will not represent a maximum allowable P^*.

To get a solution for vent surface area which maintains the maximum allowable P^* the point which is the steepest gradient of the curve must be taken. Using that gradient line, apply the equations (6), (D) or (F) (whichever is chosen as appropriate).

The vent area calculated from this will be the minimum required to absolutely ensure that the P^* designated represents a maximum allowable P^*. (safety margins factored in)

These equations, which dictate the number of vents required to prevent roof loss on a given building may be verified using a wind tunnel test.

SOME POINTS FOR OVERALL SYSTEM SETUP

In many buildings/houses there may be a space below the roof.

See Fig 15a

The vent system must be in place between space A&B space B&C and space C&D.

Between floors a stairway will probably be sufficient surface area (allow sufficient volume flow)

Rooms with doors that might potentially be closed must have vents. One would choose from equations (6), (D) or (F) to calculate the surface area of venting necessary to evacuate each room's volume.

See fig 15b

See fig 15c

See fig 15d

The flow route may be designed as one wishes, but everything must flow out through the roof in this open, free-flowing vent system.

EAVES AND PORCH/VERANDAHS

It will also be necessary to place vents in the eaves and any porches on a building. What tends to happen in these regions is a build-up of pressure (still air) away from the building.
See fig 16a

See fig 16b

In order to quantify the vent area required place pressure sensors in the eaves and porch of a model structure. Then blow worst-case scenario test winds over the model and add vents until the acceptable P^* is achieved. A vent number/area is thus generated. Blow winds from all directions and use the maximum vent number/area value generated.

VENT PLACEMENT

The area calculated as being the minimum required to ensure that a roof does not blow off could be divided up into many vents, or it could be built as one giant vent. This system is designed to work when the whole roof (and thus the entire minimum required venting) is exposed to the high wind situation. The scenario depicted below shows a situation that requires a modification to the system's parameters. The pressure decrease due to high winds only occurs where there is high-speed airflow.

See fig 17

If wind speeds are high at A, and very low at B a vent where low wind speeds occur does not experience a pressure difference that would contribute to the evacuation of the building's air. There is also of course no lift force exerted on the roof at this point and thus no need to evacuate air to effect a limitation of pressure difference for that part of the roof. However, at point A where high-speed winds are blowing, the entire minimum venting area required would need to be present. (This assumes that it is possible to experience a worst-case scenario pressure drop at one end of the roof and no pressure change at the other.)

In order to quantify the possibility of, and if necessary effect control of this situation, wind sheer data from storm events must be collected. This wind sheer data would give a value for the shortest distance over which winds blowing at high speeds and winds blowing at low speeds could be simultaneously measured. (Wind sheer) This distance, if it should be small enough, (e.g. 30 feet) would be used as a guide. The building's entire calculated minimum vent area (as per equations 6, D, or F) would have to be installed every 30 feet. If the distance was 500 yards then this adjustment would not be necessary as very few buildings are that long.

As a general guideline, it is better to have the minimum required venting area divided into several vents and spread evenly across the roof.

Studies have been done, which map the intensity of pressure drop on different sections of a roof. Using this data, zones of highest-pressure drop could be given a proportionately higher concentration of vents. The report that I viewed involved tests done on a horizontal shed like roof. Data from all common roof angles would have to be generated and analyzed before optimal vent concentration patterns could be designed.

See fig 18

It is also important that the profile of a given building be studied. The calculated area of venting required to keep the roof on, must be the area of venting exposed to high winds, regardless of their direction.

See fig 19

The design of the above building means that the minimum possible roof surface area exposed to high wind is ½ of the total roof surface area. The calculated minimum surface area of venting required, must therefore be present on both sides of the roof.

It is apparent that the house profile must be studied, and the direction from which the wind blows over the least roof surface area ascertained. That roof surface area must have the calculated necessary area of venting to prevent roof loss. The same formula must be applied to every wind direction and related windward roof surface area exposed.

CLAIMS

I claim as my invention:

Rule126

2 ~~1)~~ A roof vent system that limits the pressure difference that can occur across a roof to a set value. This system uses vents for the purpose of preventing the occurrence of a pressure difference greater than a specific set value across a roof (across a roof meaning between the interior and exterior of a building). This involves an understanding and use of a vent's ability to limit the maximum pressure difference that may occur, as opposed to previous art, which uses vents as pressure equalization or pressure relief tools. (Reference may be made to previous text for greater detail)

The vents used pass through the roof connecting the interior of the building with the outside atmosphere.

a) I have written equations that take data for the worst-case scenario pressure change above a building, the volume of the building and the pressure difference that the roof components of the specified building will tolerate. These equations are used to give a value for the cross-sectional area/number of vents required in the system for each given building. Once this venting area required to limit the pressure difference is arrived at there are three more parameters governing its placement.

i) The calculated area of venting must be placed such that that venting area is 'visible' to winds blown from each and every direction. (i.e. the calculated venting area is exposed to windward for all wind directions. The positive effects on air evacuation of the pressure drop on the turbulent drag / leeward side of the building are discounted {They represent a safety margin})

ii) The venting area is spread evenly across the roof, with concentrations weighted in correlation with pressure values measured for the different areas of a roof. (A typical value for vent concentration might be on average one vent per 200sq feet {an absolute value will depend on the volume of the building and so will vary slightly from structure to structure.}

iii) Wind sheer data is used to indicate the minimum length of windward facing roof for which the calculated vent area is sufficient.

2) I also claim the design of the vents specified for use in this system. I have submitted details of two designs for the vents to be used in the system. These designs represent the preferred embodiment of vent type. They are as follows:

Vent A has the following properties:
(Please see Figs 4a through 4f for diagrammatic representations)

7) Cap prevents rain from entering, (even most horizontally blown rain).
8) Cap is smaller than base plate so that bars slope in. This makes it more difficult for blown debris to catch on the vent.
9) Vertical bars are spaced such that the gap size doesn't allow bees access. (vents
4J cannot become hive sites)
10) Any water that does enter the vent shaft is collected and channeled through a tube into the drains. The tube might alternatively direct the water outside the building, if this proves easier.
11) The central plug is 'free floating' on a central shaft. Its weight / area is, let us say 60%
5J of the maximum allowable pressure difference. This means that at a pressure difference greater than 60% of the maximum allowable the plug will be pushed up, thus opening the vent. (The 60% figure is set so that the vent will be open by the time the maximum allowable pressure difference is reached. I.e. wind acceleration from 60% to 100% does not outpace the speed at which the vent opens. This 60% value
5F might need to be 50% or 90%, whichever is calculated as appropriate.)
12) Once the central plug is pushed up it acts like an airplane wing. Air rushing through the vent 'flies' the central plug up on its shaft. The vent stays open as long as high-speed winds are blowing through it. When the wind speed drops the plug sinks down to close the vent.

Vent B has these following properties:
(Please see Figs 5a through 5e for diagrammatic representations)

6) Cap prevents rain from entering, (even most horizontally blown rain).
7) Cap is smaller than base plate so that bars slope in. This makes it more difficult for blown debris to catch on the vent.
8) Vertical bars are spaced such that the gap size doesn't allow bees access. (vents cannot become hive sites)
9) Any water that does enter the vent shaft is collected and channeled through a tube into the drains. The tube might also direct the water outside the building, if this proves easier.
10) The central plug is pushed open by a spring. A pressure difference-sensing device triggers the spring. The pressure-sensing device is set to trigger at a fraction of P^* (say 60%) such that the vent is opened before P^*, the maximum allowable pressure, is reached.

These two vent options are to be placed in positions and in concentrations dictated by the parameters outlined in section 1 above.

ABSTRACT

This disclosure is about a roof vent system that acts to limit the pressure difference that can occur across a roof due to the effects of high wind. Equations that relate the worst-case scenario pressure drops above a roof with the volume of the building are used to generate a specific venting area required for each structure. This venting area will act to limit the pressure difference that can occur across that roof to a set value. This represents a quantifiable solution using vents in a system to achieve the particular objective of pressure difference limitation. The disclosure describes the development of these equations and details two vent designs that represent the preferred embodiment. Vents are cheap and easily installed as a retrofit into existing buildings making this quantified venting system perhaps the simplest, most certain, and most cost effective means of preventing roof loss in high wind events.

SEQUENCE LISTING

Not Applicable

10/068,935
Rec 5/23/03

DRAWINGS

Graphical representation of the distinction between using a vent to equalize pressure and my vent system which prevents a specific pressure difference from occurring (arbitrary values and units used)

Fig 1a

Use of vents to equalize pressure

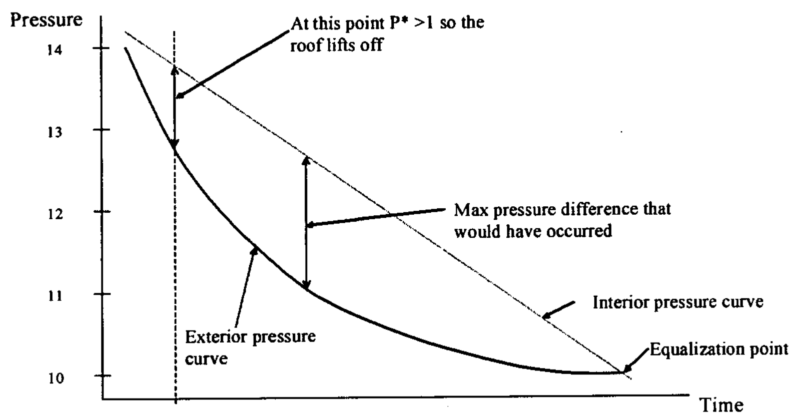


Fig1b

Use of vents to limit the pressure difference across a roof

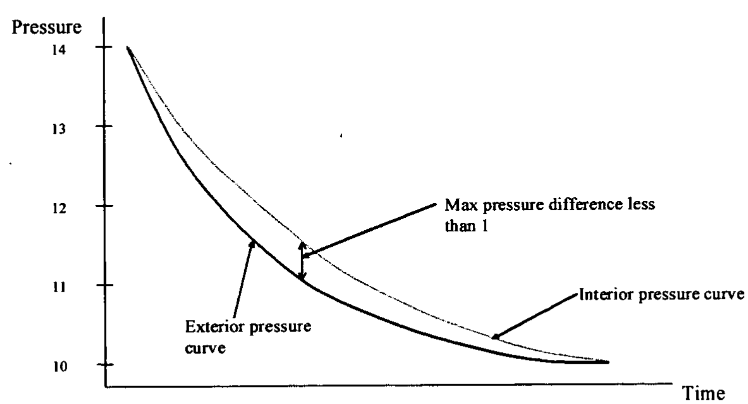


Fig 2

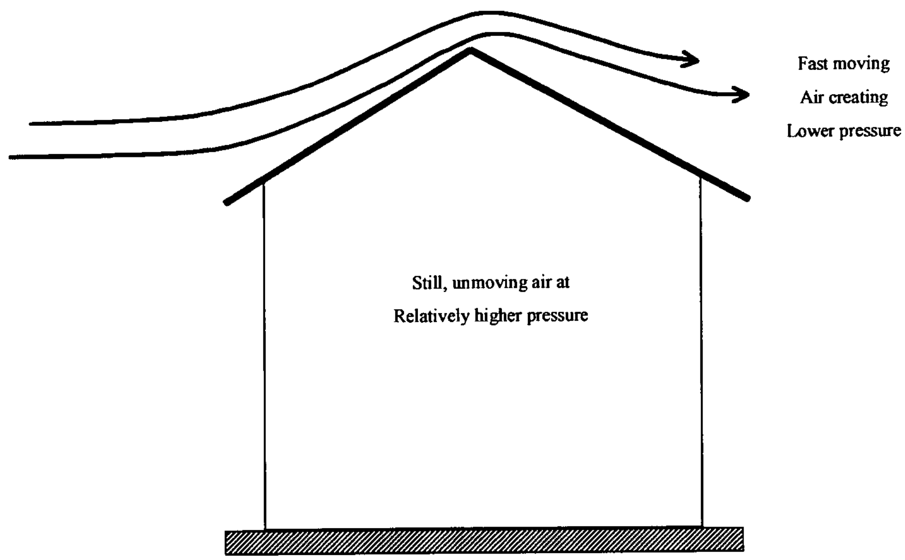

Fast moving
Air creating
Lower pressure
Still, unmoving air at
Relatively higher pressure

Fig 3

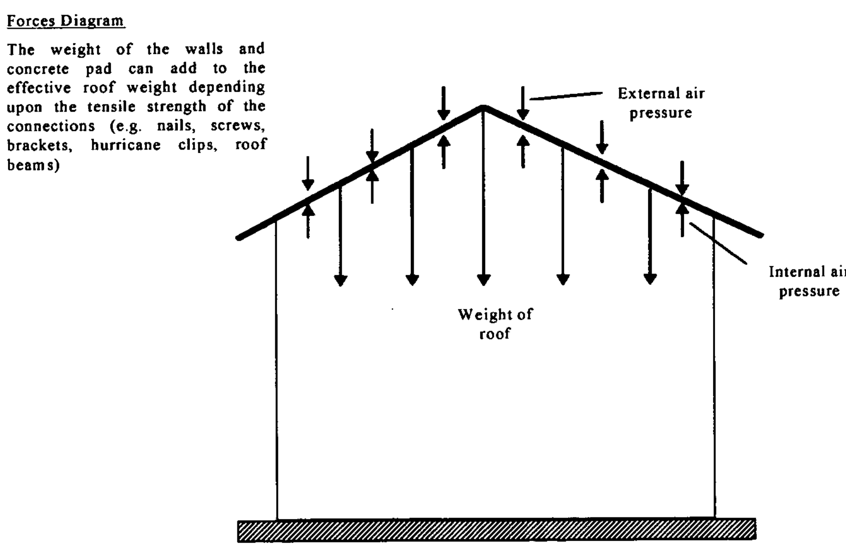

Forces Diagram
The weight of the walls and concrete pad can add to the effective roof weight depending upon the tensile strength of the connections (e.g. nails, screws, brackets, hurricane clips, roof beams)
External air pressure
Internal air pressure
Weight of roof

Fig 4a

1) Vent design (A)

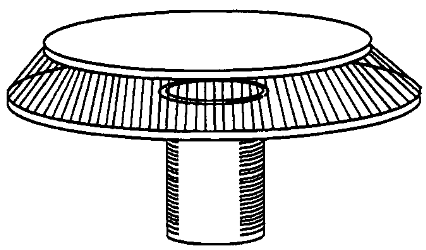


Fig 4b

Cross-sectional view

Plug in closed position

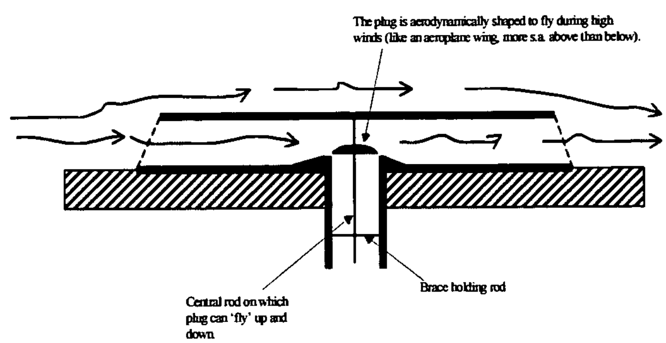


Fig 4c

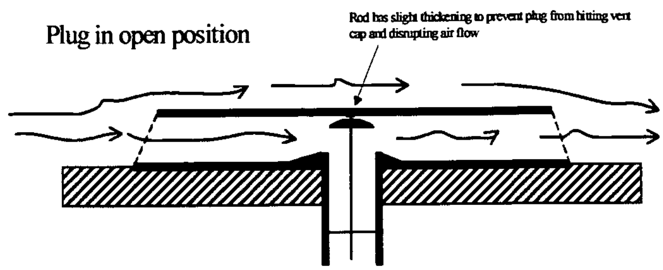


Fig 4d

Details of plug shaft and brace mechanism

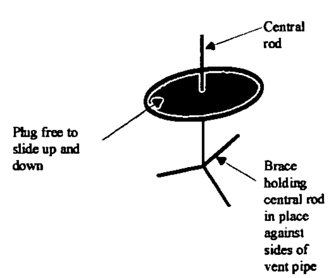


Fig 4e

View from above

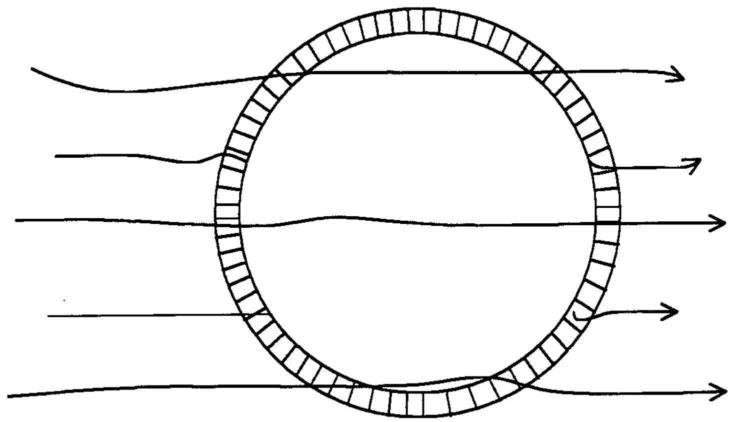
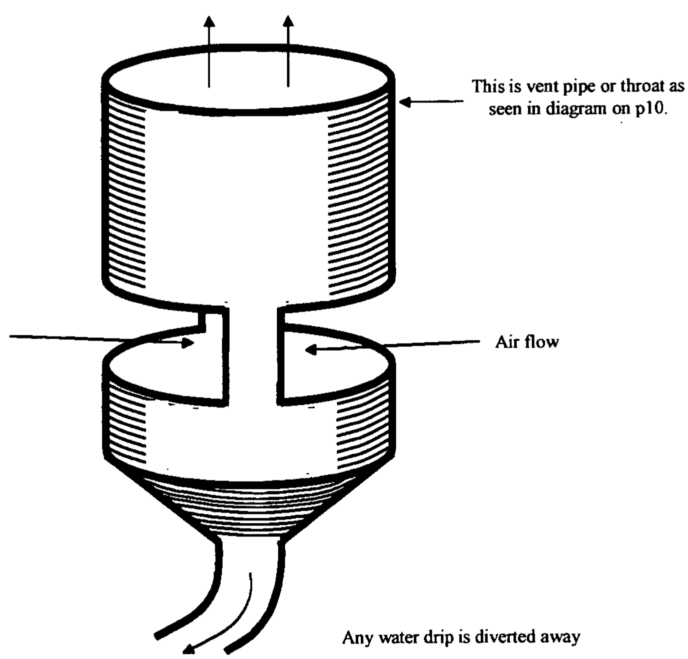


Fig 4f



Vent design B

Fig 5a

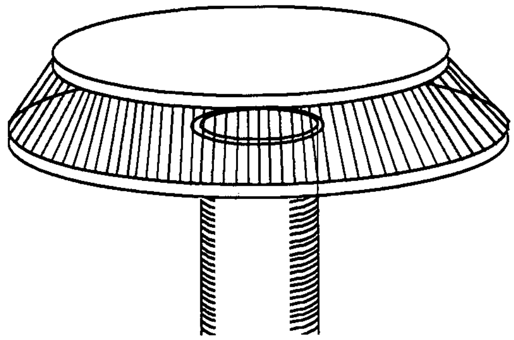


Fig 5b

Cross-sectional view

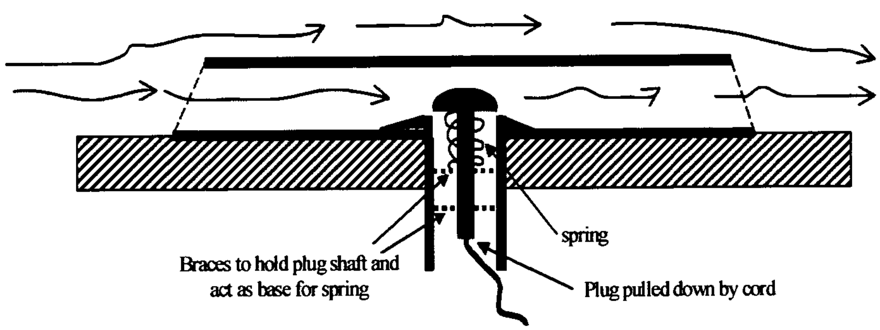


Fig 5c

Details of plug/braces and shaft mechanism

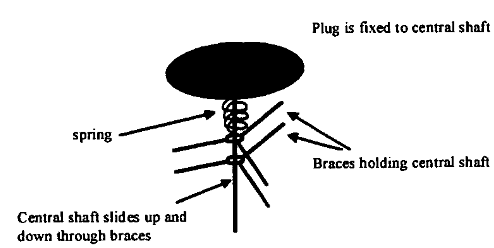


Fig 5d

View from above

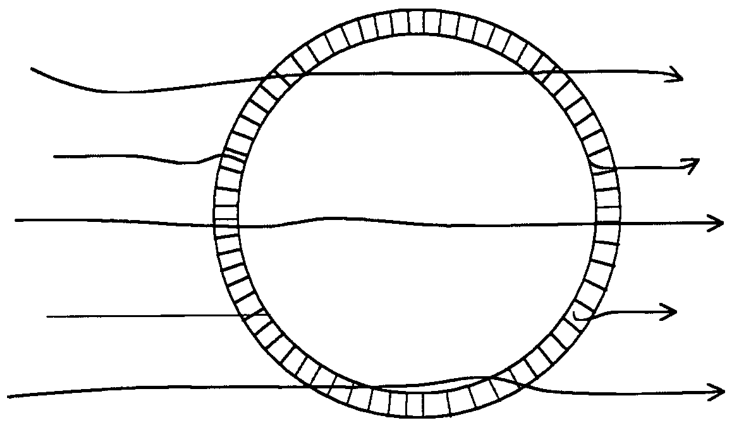


Fig 5e

Optional water removal mechanism

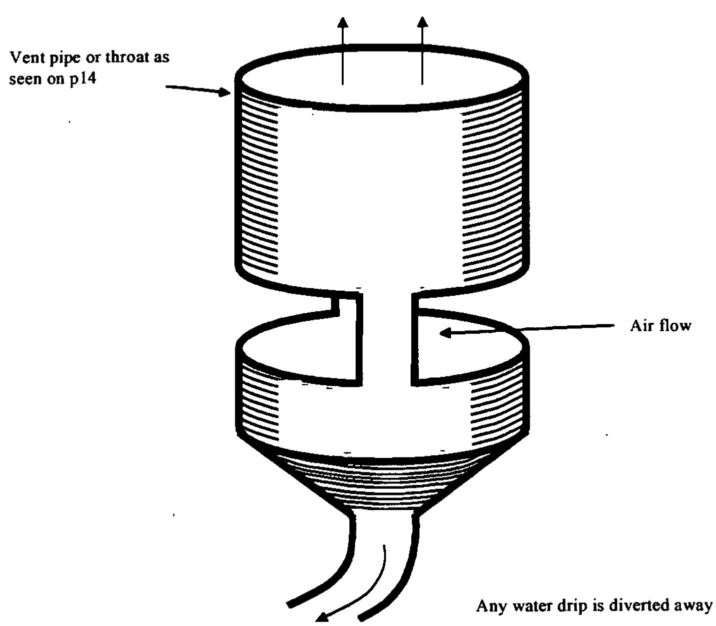


Fig 7

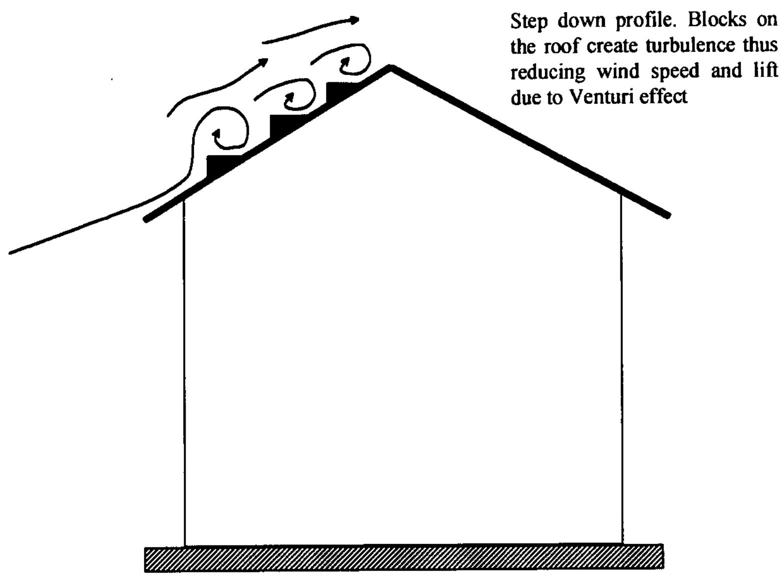


Fig 8

Graph of Maximum Measured Acceleration of Wind from 0mph to Maximum Wind Speed Expected (Hurricane protection speed)

(an example, not real data)

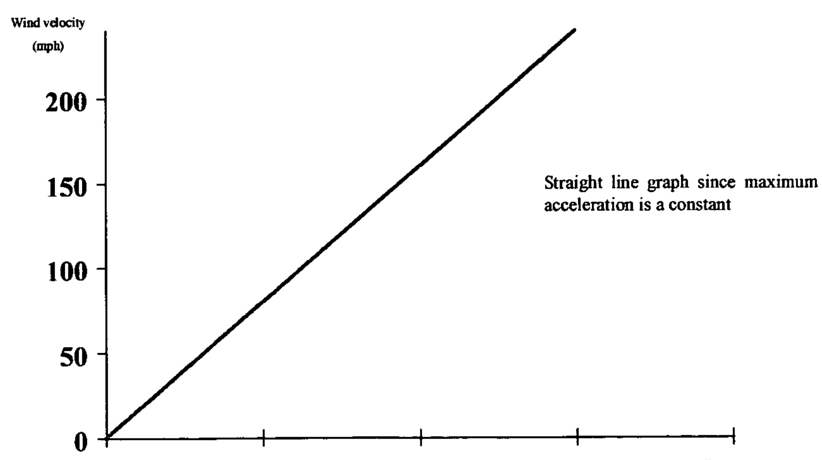


Fig 9

Potential Graphs of pressure w.r.t. Velocity of Wind
(actual graphs will take the form of one or some combination of the following)

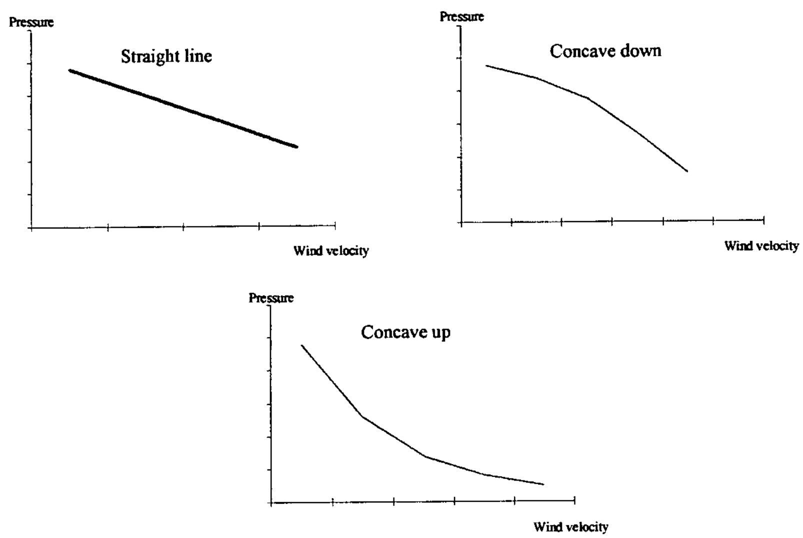


Fig10

Graph of Pressure w.r.t. Time
(graph will be in one or some combination of these forms)

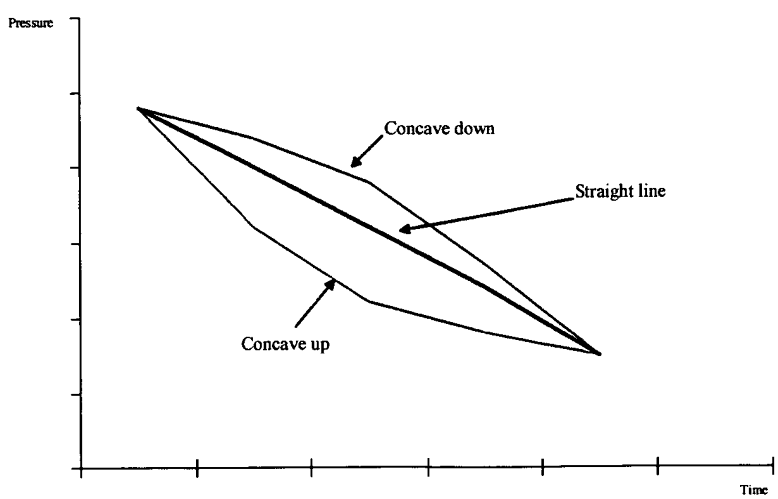


Fig 11a

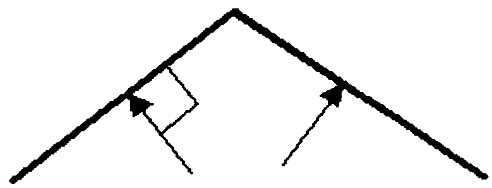


Fig 11b

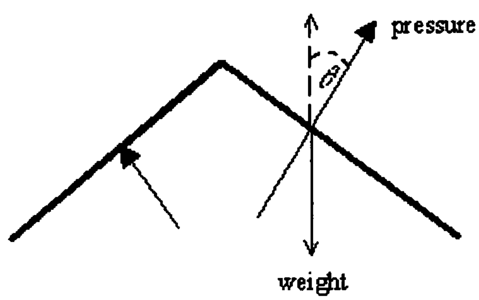


Fig 12

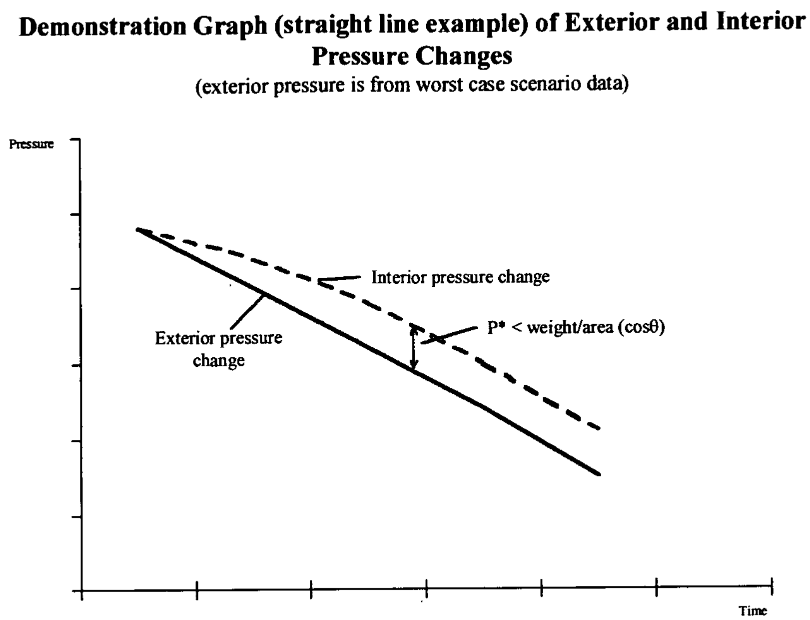

Demonstration Graph (straight line example) of Exterior and Interior Pressure Changes
(exterior pressure is from worst case scenario data)
Pressure
Interior pressure change
P* < weight/area (cosθ)
Exterior pressure change
Time

Fig 13

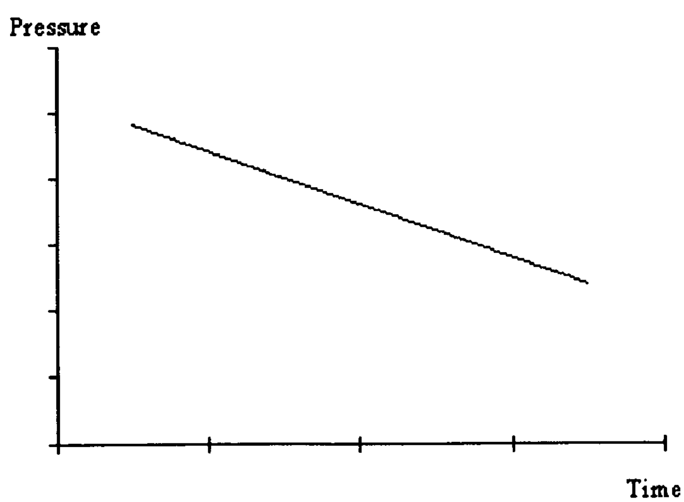

Pressure
Time

Fig 14

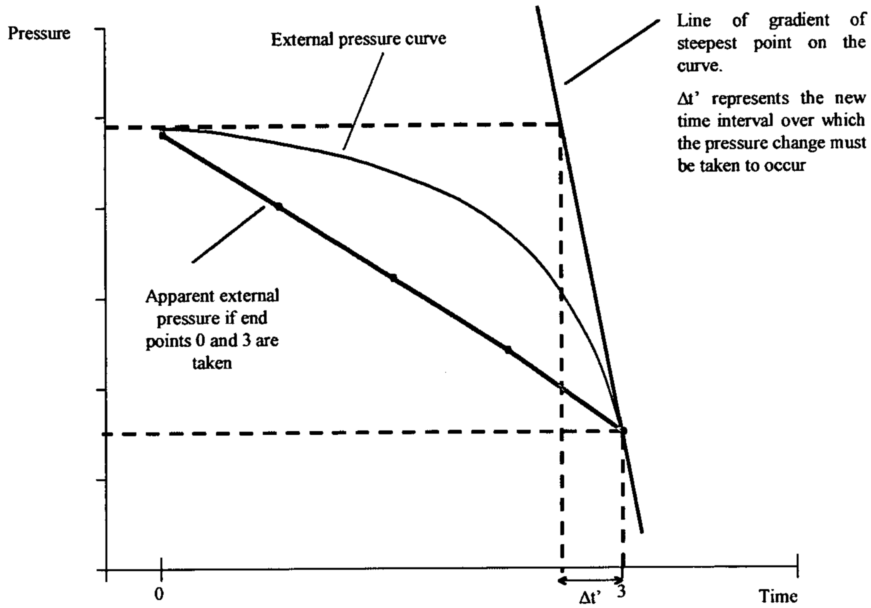

Pressure
External pressure curve
Line of gradient of steepest point on the curve.
Δt' represents the new time interval over which the pressure change must be taken to occur
Apparent external pressure if end points 0 and 3 are taken
0
Δt'
3
Time

Fig 15a

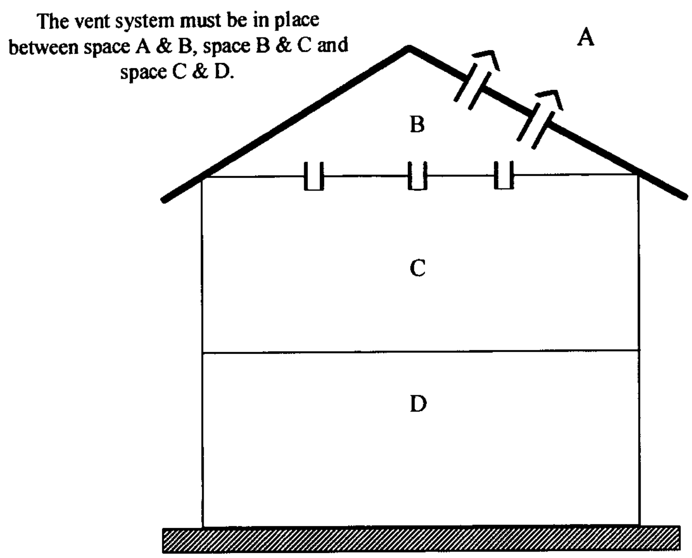


Fig15b

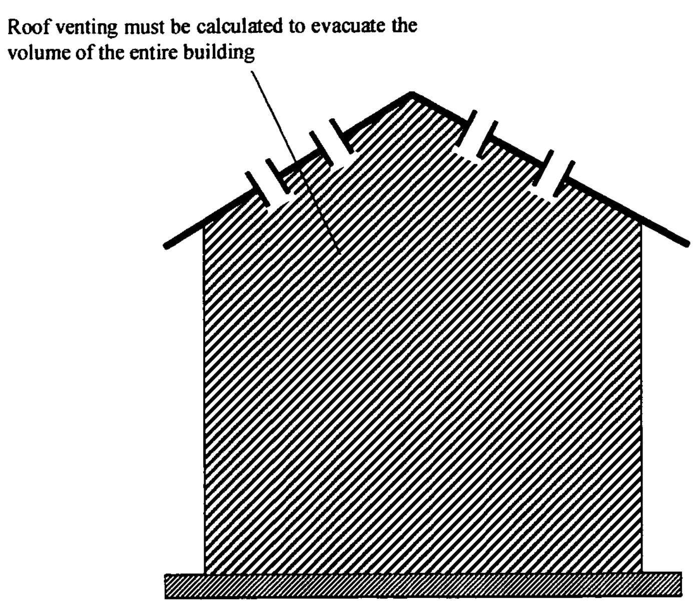


Fig 15c

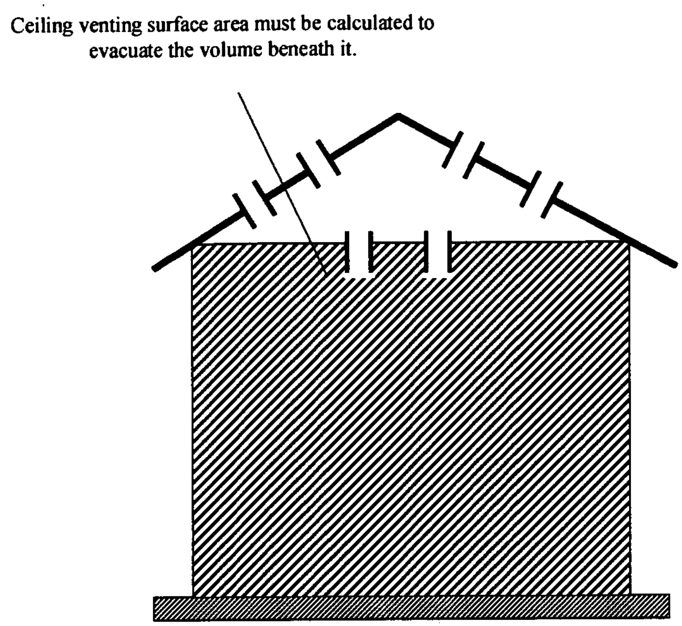


Fig 15d

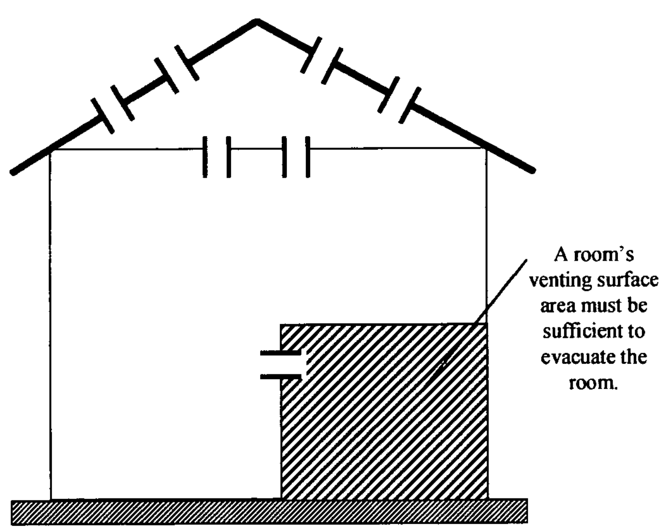


Fig 16a

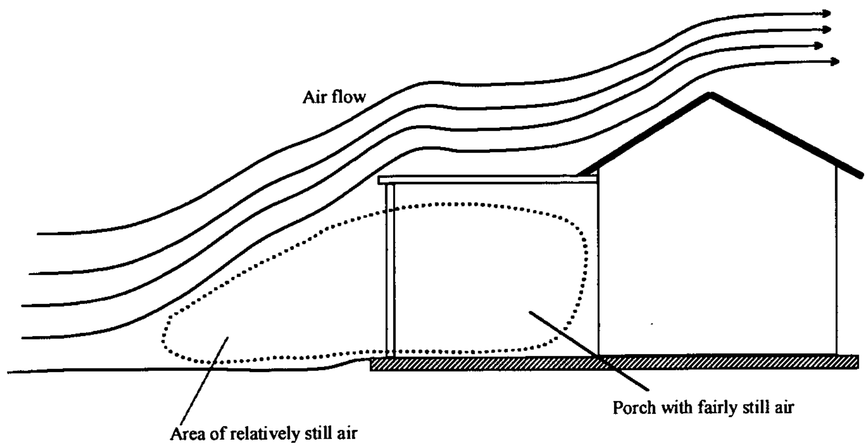


Fig 16b

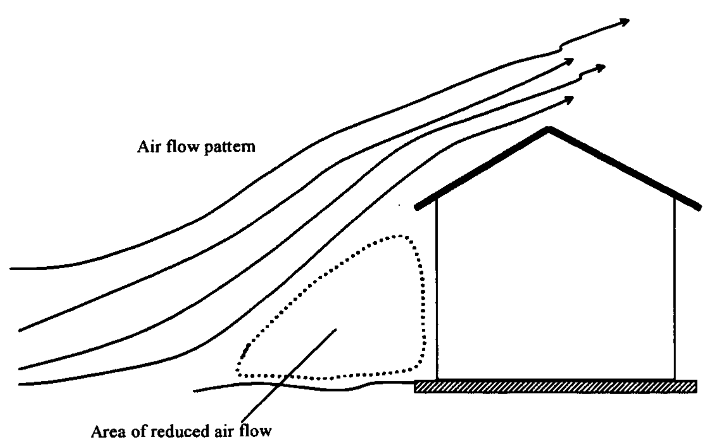


Fig 17

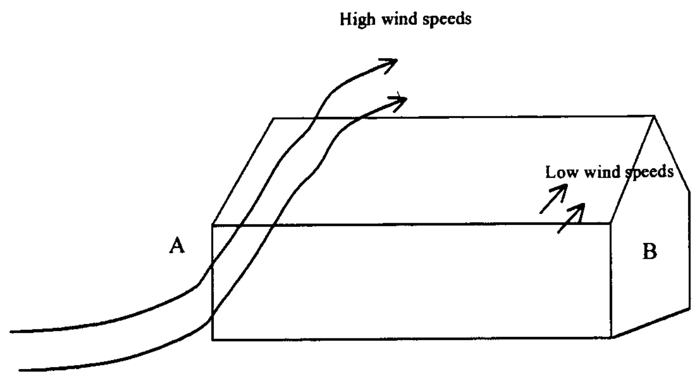


Fig 18

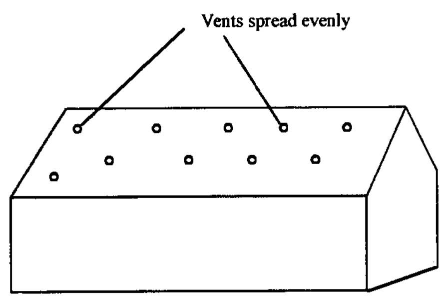


Fig 19